

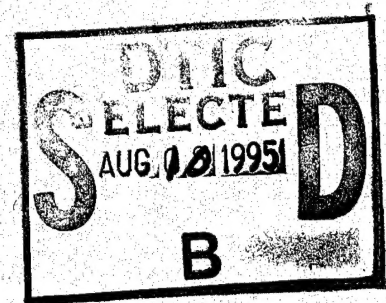
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Technical Report ARCCD-TR-95003

**CONTROLLED EXPERIMENT TO DETERMINE FACTORS  
AFFECTING TRACER PERFORMANCE**

John R. Middleton  
Kristen Vogelsang



July 1995



US ARMY  
TANK AUTOMOTIVE AND  
ARMAMENTS COMMAND  
ARMAMENT RDE CENTER

**U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND  
ENGINEERING CENTER**

Close Combat Armaments Center

**Picatinny Arsenal, New Jersey**

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13. ABSTRACT (Maximum 200 words)  This report details efforts to determine what process variables had the greatest impact on 7.62-mm M276 Trace performance. The report includes a brief discussion of production problems encountered, efforts to resolve the problems and reinitiate production, development and execution of a test plan to define the process, and the analysis of the data using the Taguchi Method of Quality Engineering.			
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## **OBJECTIVES**

The objectives of this study were to investigate which dry blending production variables affect the trace performance of the 7.62-mm M276 Dim Trace Cartridge and to fine tune the existing process based on these results.

## **BACKGROUND**

The 7.62-mm M276 Dim Trace Cartridge was originally developed in the late 1960s for use with newly developed night vision technology. Night vision devices (image intensifiers) amplify ambient light enabling the user to locate, identify, and fire upon targets in darkness and low light conditions. Standard 7.62-mm M62 tracer ammunition yields a bright red trace signature. When amplified, this signature caused instrumentation shutdown and blooming, especially at high rates of fire. Both occurrences resulted in loss of target acquisition. Moreover, instrumentation shutdown temporarily blinds pilots causing a severe safety problem.

The M276 uses R-440 trace composition and provides a reduced signature visible only through Night Vision Equipment (NVE) and invisible to the unaided eye. Due to the end of the Vietnam conflict, budgetary constraints in the early 70s, and the unrefined night vision technology, the Dim Trace Program was discontinued prior to full type classification.

This cartridge was revived in 1990 when Army Special Operations found records pertaining to the Dim Trace Program. Night Vision Equipment had become a standard item for many units and the same problems still existed when using standard trace ammunition. Full production was initiated for U.S. Army Special Operations in FY 92 and type classification was accomplished in March 1993.

In October of 1992, the M276 Dim Tracer experienced a degradation in trace performance that eventually led to a shutdown of production at Lake City Army Ammunition Plant (LCAAP). The problems reported involved short and/or spotty trace signatures which were often difficult to discern even with NVE. By short and/or spotty, it is meant that the trace signature would either not meet the required 850 yd requirement or be blinking on and off during flight or both.

To resolve the situation, a cooperative effort between the U.S. Army Armament Research, Development and Engineering Center (ARDEC) and LCAAP personnel was launched to determine the cause of the problem, find the appropriate solution, and reinstate production. This effort eventually led to a new dry blend procedure which provided a substantial improvement in the trace signature and length of trace.

The previous method involved dissolving calcium resinate into a methylchloroform/ethyl alcohol solution. This solution was then added to the remaining dry chemicals. Two possible premises were thought to be contributing to the performance problems. It was felt that stratification of the calcium resinate in the holding tank would result in a non-homogenous trace mix. The second premise was that some water molecules remained within the mix after drying and were reacting with the chemical components resulting in degradation of the mix over time. Each of these premises was supported by test data. Some samples of charged projectiles showed immediate poor trace performance when tested. This immediate poor performance was usually contributed to a non-homogenous mix which would be affected by stratification of the calcium resinate in the holding tank. This would result in an improper fuel to oxidizer ratio. Some samples would degrade over a period of time due to moisture trapped within the mix. Initial tests of charged projectiles performed over the first 2 to 3 nights would provide good results. Testing of these same samples 1, 2, and 3 wk later would reveal consistently decreasing results. As ethyl alcohol has a permissible moisture content of 5%, it was decided to use isopropyl alcohol which has a permissible moisture content of 0.5%. Again, it was observed that samples which initially looked acceptable would also degrade over a period of a few weeks. It was only after developing a completely dry blend procedure that trace performance returned to acceptable levels.

The dry blend procedure resulted in a mix with vastly different flow characteristics which required several adjustments to the charging equipment. Because of the limited volume in the tracer cavity, the dry blended mix, being lighter and fluffier, greatly reduced the amount of mix which could be put into the tracer cavity at each charging station. After consolidation, this resulted in a much lower column height. However, the dry blend composition burned much slower and actually increased the burn distance past the required 850 yd. The tracers could still be seen burning in the bunker at 925 yd for 1 or 2 sec.

To help prevent any future problems, a test plan was developed to determine what variable(s) of the new blending procedure could adversely affect trace performance.

## **TEST PLAN AND EXECUTION**

To develop a test matrix which would clearly define the effects of production variable(s) upon performance, the Mathematics Department at the U.S. Military Academy at West Point was contacted for assistance. A preliminary full factorial experimental design was developed. The matrix initially consisted of all variables and combinations thought to potentially affect the trace performance. However, the matrix was too cumbersome and time-consuming to be performed within funding constraints.

An alternate experimental design was developed using a Taguchi Method based on seven test variables. The seven variables were chosen by personnel from ARDEC and the Olin Corporation engineering staff assigned to the dim trace production problems. Each variable was examined at two levels in an attempt to determine at which extreme, if any, that variable could affect trace performance.

As production had already been reinitiated using the dry blend procedure, the test matrix focused solely on variables specific to the dry blend procedure, i.e., no samples with methylchloroform/ethyl alcohol solution were included.

The variable descriptions and the rationale for their selection are as follows:

- Percentage of calcium resinate - Performance may be affected by varying the fuel to oxidizer ratio in the trace composition. (Level 1: 7.5%, Level 2: 10%)
- Dry blend time - The final performance may be affected by the homogeneity of the composition. A shorter blend time may result in a less homogeneous composition and may vary the round-to-round performance. (Level 1: 15 min, Level 2: 30 min)
- Amount of ignitor - A greater amount of ignitor may impart more energy on the trace mix and provide a brighter and more consistent burn. (Level 1: 0.065 mg, Level 2: 0.090 mg)
- Type of ignitor - An ignitor with a higher flame temperature would accomplish the same as the amount of ignitor. [Level 1: I-136, Level 2: I-136 modified (2% magnesium)]
- Compression pressures - A long history of data describes the affect of compression pressures on standard tracer's performance. This variable was added to determine the most effective pressures when compressing the dry blend. (Level 1: 75 ksi, Level 2: 105 ksi)
- Calcium resinate particle size - The new dry blend procedure resulted in a lighter and fluffier mix than previously used and resulted in some loading problems. This variable used a larger sized resinate hoping to improve flow characteristics. (Level 1: Regular, Level 2: Large)
- Amount of trace mix - By increasing the amount of mix, despite the lighter and fluffier mix, it was anticipated that a longer trace signature would result. [Level 1: Regular, Level 2: More actual mix compressed in the 1st dump (0.360 mg)]

Sample tracer cartridges were manufactured according to the following matrix. Eight different trace mix formulations were produced (samples 1 through 8) in accordance with the levels noted for each of the variables A through G (i.e., sample 1 was prepared with all variables at Level 1).

<u>Sample</u>	<u>Levels</u>						
	<u>a</u>	<u>b</u>	<u>c</u>	<u>d</u>	<u>e</u>	<u>f</u>	<u>g</u>
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Two hundred rounds were randomly selected from each of the eight matrix samples and tested over a 2 night span. Each night 100 rounds of each matrix sample was fired over four weapons and separate data sets were taken.

All testing was performed per SCATP-7.62 mm (Ammunition Ballistic Acceptance Test Methods - Test Procedures for 7.62mm Cartridges), MIL-C-50704A (Military Specification - Cartridge, 7.62mm: Dim Tracer, M276), and Olin Corporation Standard Operating Procedures.

The first set of data consisted of the standard trace performance results and were based on the standard definitions of defects as stated in MIL-C-50704A. Performance testing used three observers at two ranges. One observer with NVE and one without NVE reported defects from an observation house adjacent to the gun room. The observer at the gun house equipped with NVE was responsible for calling all defects cited in MIL-C-50704A such as short trace, inconsistent trace, delayed trace, etc.

For the observer without NVE, the specification criteria states that cartridges exhibiting full luminosity greater than 50% of the distance shall be considered defects. However, due to the process and user preferences, this observer usually classifies any visible trace more than a momentary spark as a full luminosity during lot acceptance testing. The same procedure was used for this test.

The third observer was in an observation house at 450 yd from the gun house. This observer was also equipped with NVE and used the same criteria as the NVE equipped observer at the gun house.



The second set of data was an independent numerical assessment, established specifically for this matrix experiment, of the trace signature by an ARDEC representative equipped with NVE. A grade of zero to three was assigned to each shot and then each sub-lot was averaged for comparison purposes. The values were assigned as follows:

<u>Rating</u>	<u>Criteria</u>
0	Totally blind
1	Short and spotty
2	Either short or spotty (but not both)
3	Consistent signature reaching desired length

Defects, such as delayed trace, generally caused by improper ignitor ignition were not called by the ARDEC observer.

For the test, four barrels were used each night and this data was used to determine the effects of barrel wear on trace performance.

## RESULTS

Using the Taguchi Method of Quality Engineering to analyze the data, the effect of each factor (variables A through G) on trace performance were examined. Three data sets and data sub-sets were available to support this analysis. These data sets and their sub-sets were:

- ARDEC developed rating criteria
  - Rating of all criteria 2 defects
  - Rating of all criteria 1 defects
  - Rating of all criteria 0 defects
- Visible traces by the non-NVE equipped observer (those visible traces not classified as a specification defect, but sufficient enough to be a concern to the user, i.e., visible at less than 100 yd which would indicate a possible firing position to opposing forces.)
- Standard defects as called by all three observers during normal production

As each of these are summations of defects, either specification mandated or developed for this test, the number of defects would be minimized using Taguchi's Smaller the Better Analysis.

## First Evaluation - Criteria 2 - Short or Spotty Trace Performance

The first data set analyzed was the data set consisting of all rounds for which a rating criteria of 2, either short or spotty (but not both), was assigned. A table was developed for each nights firing by summing up the number of shots per barrel per sample per night that received a score of 2. The first nights firing tabulation is presented as follows:

	<u>Defect</u>	<u>Barrel No.</u>			
		<u>4C</u>	<u>10C</u>	<u>12C</u>	<u>13C</u>
PS 1	2	15	17	7	13
PS 2	2	1	1	4	3
PS 3	2	15	7	12	16
PS 4	2	0	2	2	0
PS 5	2	6	7	9	5
PS 6	2	0	0	1	0
PS 7	2	6	13	8	15
PS 8	2	0	0	0	0
Totals	2	43	47	43	52

PS = Process sample

Barrels 4 and 10 were those considered old versus 12 and 13 which were considered new by round count.

A similar table for the second night was also developed and the data from each table was inserted into a computer program to perform the Smaller the Better Analysis.

Taguchi's Analysis calculates a signal to noise (S/N) ratio which was, in essence, the number of times the product variable was involved in a defect. From these calculations, a second table was generated which tabulates the S/N for each level and each variable, the quantitative absolute difference between the levels for each process variable, and ranks the quantitative difference from largest to smallest. The larger the difference the greater the effect of that particular process variable upon performance. For this particular example the Smaller than Better Analysis revealed the following:

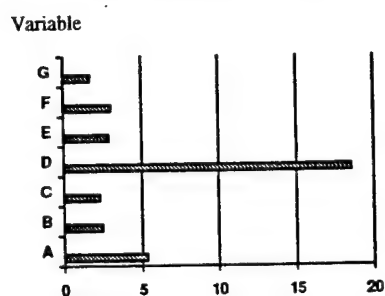
<u>Effects</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>G</u>
L1	14.753	-13.345	-13.264	-21.365	-10.630	-10.567	-11.217
L2	-9.424	-10.832	-10.913	-2.812	-13.547	-13.610	-12.960
/L1-L2/	5.329	2.513	2.351	18.553	2.917	3.043	1.743

Rank	2	5	6	1	4	3	7
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Most significant: D2, A2

The variables that control the process are those that have an influence on the S/N ratio. If there is a large difference in S/N when the variables are at different levels, this shows a strong influence. The previous table identifies the effect each variable had on the S/N by calculating the difference between levels. Of greatest significance are variables D and A, so it was said that those are the controls in the manufacturing process. It was desired to maximize S/N ratio when optimizing the process and minimizing defects. Variables D and A were at maximum S/N when at level 2, i.e., -2.812 for variable D versus -21.365. This corresponds to the use of the modified I-136 ignitor mix (D2) and 7.5% calcium resinate (A2). The magnitude of each variable can be easily seen graphically:

/L1-L2/ for Criteria 2



/L1-L2/

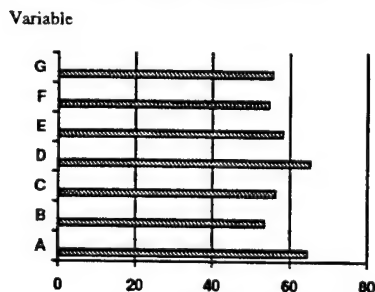
Most significant: D2, A2

For the remainder of the discussion only the graphical data will be used. Which level of each variable that would provide the preferred trace signature/performance will be discussed separately.

## Second Evaluation - Criteria 1 - Short and Spotty Trace Performance

The second analysis performed was on the amount of criteria 1 defects found. Although not as apparent, the results indicated controlling variables were D and A and recommended level 2 for both.

/L1-L2/ for Criteria 1



/L1-L2/

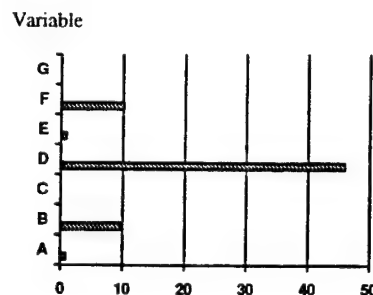
Most significant: D2, A2

While this analyses for the ARDEC developed criteria for 1 and 2 defects provided valuable information, it raised an issue pertaining to the visibility of certain samples to the unaided observer. The most significant factor in each analysis was the type of ignitor needed to reduce short and/or spotty tracer signatures. The Modified I-136 contains 2% magnesium. Addition of magnesium to the trace mix increases the overall visibility of the trace. In fact, during these tests, a high number of visible traces were seen by the naked eye observer at the gun house. These defects were not classifiable under the specification as a defect in that they did not exceed 100 yd. However, any visible trace is undesirable to U.S. Army Special Operations, the primary user of this round, as it will cause slight blooming in the NVE and could reveal a gunner's position to opposing forces.

### Third Evaluation - Variables Affecting Visible Trace

Those rounds that exhibited a trace visible to the naked eye were noted along with all other defects during the firing. An analysis was performed on the naked eye observer's calling of all visible traces regardless of length.

/L1-L2/ for Visible Traces



/L1-L2/

Most significant: D1, F2, B2

The results of this analysis indicate that once again variable D is controlling the process, however, this time suggesting level 1 to optimize the process. This further proves that the modified ignitor was aiding in the reduction of short and/or spotty traces; however, it was taking the performance to the other extreme, creating traces so visible that they could be seen with the naked eye. Results of this analysis recommend that to reduce the number of visible traces, the standard I-136 ignitor mix should be used.

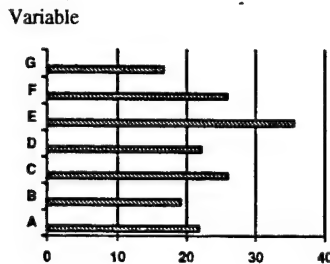
This also brings into question the applicability of changing the percentage of calcium resinate as recommended by the first two analyses. Tracer performance is highly dependent on the burn temperature and the fuel to oxidizer ratio. The higher burning temperature I-136 with 2% magnesium would definitely require an increase to the amount of fuel required to meet performance criteria.



#### Fourth Evaluation - Overall Trace Quality

The previous section was an effort to quantify the data based on the quality of the trace signature. This yielded an unacceptable result and required a rethinking of the analytical approach. The next analysis focused on the actual amount of specification defects seen by the observers and by the amount of blind traces seen by the ARDEC observer. While the visual quality of the signature was of concern, one must first have a signature that meets the standard specification requirements and reaches the desired lengths to quantify. An analysis of defects called by the observers revealed the following:

##### /L1-L2/ for Observers Spec Defects

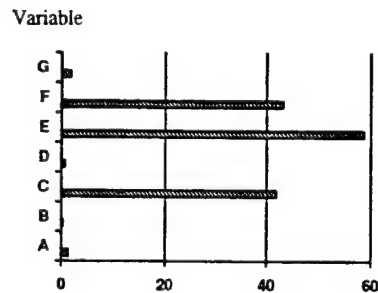


/L1 -L2/

Most significant: E1, C1, F1

The analysis of the blinds (i.e., those scored with a zero) as seen by the ARDEC's observer is as follows:

##### /L1-L2/ for ARDEC Blinds



/L1 -L2/

Most Significant: E1, F1, C1

The same three factors at the same levels, were found in each analysis to have a significant impact on the tracer performance. These variables were amount of ignitor (C), compression pressures (E), and the calcium resinate particle size (F).

According to the matrix, the greater amount of ignitor adversely affected the ignition of the R-440 dim trace composition. This disproved the theory that more ignitor would provide a better initiation of the R-440. Instead, the opposite occurred and it appeared to hinder the burn of the R-440 resulting in a reduced burn. This may have been caused by extra slag build up from the extra ignitor. From the original Frankford Arsenal developmental reports, it is known that slag buildup will adversely affect the performance of the R-440.

Higher compression pressures provided improved trace performance. Years of experience with standard trace mixes, which are denser and possess good flow characteristics, have shown that higher compression pressures yield improved trace performance. Increased compaction of the mix reduces and/or eliminates defects, such as cracks, within the trace column. These defects generally cause the mix to be mechanically affected (possibly broken up) by the barrel. This usually causes premature burning of the mix resulting in blinds at 850 yd, dim signatures at 100 yd, and early ignitions at 15 yd.

As the R-440 is lighter and fluffier, lower compressions were tried in an effort to provide a better burn of the R-440. It was thought a looser column would be easier to ignite, and once ignited, would burn at a higher temperature thus increasing the signature. However, the R-440 mix proved to burn in the traditional manner of trace compositions.

With all process changes in place (dry blend, high compression, particle size, amount of ignitor, etc.), the trace distance was now exceeding the required 850 yd. The tracers could be seen burning in the bunker, at 950 yd, for an additional 1 to 2 sec. With the defects eliminated, the quality of signature improved and was now easily identifiable through the NVE the entire length of flight.

The last variable which had a significant affect on the trace performance was the calcium resinate particle size. This larger particle size did provide one anticipated benefit in that it improved the flow characteristic of the mix eliminating several problems during charging. However, it greatly reduced the trace performance and was not deemed worth further investigation.

**Note: For each of the analyses discussed previously, the generated data sheets detailing the defects per barrel and for each night, noise levels, /L1-L2/, rankings, etc. are provided in the appendix.**

Another analysis considered was to perform a Larger the Better Analysis on the data set for all criteria 3's attempting to maximize the number of perfect traces. A problem with this methodology was that the values assigned by the ARDEC representative for the quality of the trace signature were often seen by the unaided observer. Based on the previous discussion pertaining to visible trace signatures, this analysis was discarded.

In any of these analyses, it was easily apparent from the data table that neither barrel wear or night to night differences were involved in affecting tracer performance. The number of defects were close to one another if totaled for the old verses new barrels or from one night to another.

## **CONCLUSIONS**

The objective of the test was met and production factors were found which affect tracer performance. Those factors stated previously were the amount of ignitor, compression pressures, and the calcium resinate particle size.

Since the new blending procedure was already using the levels which were deemed to improve trace performance, no additional changes to the dry blend procedure were necessary.

During the efforts to resolve the performance problems, it became clear that any excess moisture would degrade the mix once it was charged into the bullets. Some of the individual constituents involved are susceptible to absorbing moisture from outside influences. Since the implementation of the dry blend process, it is highly likely that a shift in performance would be caused by tainted raw materials or moisture acquired from somewhere within the process (i.e., leaking steam pipe in the drying bunker, excess humidity in the manufacturing area, etc.) rather than the blending process and associated procedures.

## **RECOMMENDATIONS**

1. Olin Corporation should continue to use the dry blend procedure as instituted.
2. Production of the M276 Dim Tracer should be monitored to insure the continuation of the current high level of performance.
3. Should a future problem arise, an analysis of the individual chemical constituents should be performed for moisture, purity, and possible contamination.

APPENDIX  
GENERATED DATA SHEETS



# TEST MATRIX FOR 7.62mm DIM TRACE INVESTIGATION

CONTROLLABLE FACTORS		LEVEL 1	LEVEL 2
A	CALCIUM RESINATE %	10%	7.5%
B	DRY BLEND TIME	30 min	15 min
C	AMOUNT OF IGNITOR	.065	.090
D	DIFFERENT IGNITOR	I-136	I-136 MODIFIED
E	COMPRESSION	105,000 psi	75,000 psi
F	CALCIUM RESINATE PARTICLE	REGULAR	LARGE
G	AMT R440 MIX - 1st DUMP	REGULAR (.410 mg)	LESS (.360 mg)

## NOISE FACTORS

- 1) DAY TO DAY VARIATION

## SUBSTITUTE VARIABLES

- 1) BARRELS
- 2) CALCIUM RESINATE LOT
- 3) MAG CARBONATE LOT
- 4) R440 TRACE CHARGE WEIGHT

LOW ROUND COUNT  
LOT 1 - FUSED  
LOT 1  
LOW

HIGH ROUND COUNT  
LOT 2 - PRECIPITATED  
LOT 2  
HIGH

# Samples Receiving an ARDEC Rating of 2

## Raw data and preliminary analysis

Raw data and preliminary analysis										Number of Defects								(SMALLER THE BETTER)				
										Night 1				Night 2								
L(8)										Barrel #'s				Barrel #'s								
	A	B	C	D	E	F	G	B1	B2	B3	B4	B1	B2	B3	B4	TOTAL	SUM Y^2	ndB				
1	1	1	1	1	1	1	1	15	1	17	7	13	15	15	9	14	105	1459	-22.61			
2	1	1	1	2	2	2	2	1	1	1	4	3	2	5	0	8	24	120	-11.761			
3	1	2	2	1	1	2	2	15	15	7	12	16	14	13	13	15	105	1433	-22.532			
4	1	2	2	2	2	1	1	0	0	2	2	0	0	2	1	0	7	13	-2.1085			
5	2	1	2	1	2	1	2	6	6	7	9	5	4	10	14	15	70	728	-19.59			
6	2	1	2	2	1	2	1	0	0	0	1	0	1	1	2	0	5	7	0.57992			
7	2	2	1	1	2	2	1	6	6	13	8	15	9	13	9	11	84	946	-20.728			
8	2	2	1	2	1	1	2	0	0	0	0	0	2	1	0	3	5	5	2.0412			
										5.375	5.875	5.875	5.375	6.5	5.875	7.5	6	7.875				
																				1		
																				2		
																				3		
																				4		
																				5		
																				6		
																				7		
																				8		

ndB	
1	89.0308999
2	-13.869446
3	2.04119983
4	-11.055102
5	-11.9382
6	6.02059991
7	-11.760913
8	89.0308999

Samples Receiving an ARDEC Rating of 2

Signal to Noise Ratios for Each Level and Variable and the Quantitative Absolute Differences between Levels

EFFECTS	A	B	C	D	E	F	G
L1	-14.752665	-13.345265	-13.264344	-21.36491	-10.630024	-10.56685	-11.21657
L2	-9.4243265	-10.831727	-10.912648	-2.8120817	-13.546968	-13.610142	-12.960422
/L1-L2/	5.3283388	2.51353818	2.35169679	18.5528284	2.91694397	3.04329146	1.7438525
RANK		2	5	6	1	4	3
							7

# Samples Receiving an ARDEC Rating of 1

## Raw data and preliminary analysis

L(8)	Number of Defects										(SMALLER THE BETTER)			
	Night 1					Night 2								
	Barrel #'s		Barrel #'s		Barrel #'s		Barrel #'s		Barrel #'s		TOTAL	SUM Y^2	ndB	
	A	B	C	D	E	F	G	B1	B2	B3	B4			
1	1	1	1	1	1	1	1	0	0	5	2	0	82	-10.107
2	1	1	1	2	2	2	2	1	2	2	1	1	12	-1.7609
3	1	2	2	1	1	2	2	3	5	4	7	4	127	-12.007
4	1	2	2	2	2	1	1	0	0	2	1	4	30	-5.7403
5	2	1	2	1	2	1	2	2	0	2	2	2	22	-4.3933
6	2	1	2	2	1	2	1	0	0	0	1	0	1	9.0309
7	2	2	1	1	2	2	1	3	1	1	2	2	24	-4.7712
8	2	2	1	2	1	1	2	0	0	0	0	0	1E-11	229.031
												1E-11	1E-22	

ndB	
1	89.0308999
2	-13.869446
3	2.04119983
4	-11.055102
5	-11.9382
6	6.02059991
7	-11.760913
8	89.0308999

0.75	1.5	1.375	0.75	1	2	2	1.625
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Samples Receiving an ARDEC Rating of 1

Signal to Noise Ratios for Each Level and Variable and the Quantitative Absolute Differences between Levels

EFFECTS	A	B	C	D	E	F	G
L1	-7.4039003	-1.8076446	53.097884	-7.8197289	53.9868559	52.1975054	-2.896966
L2	57.2243151	51.6280593	-3.2774693	57.6401436	-4.1664412	-2.3770907	52.7173808
/L1-L2/	64.6282154	53.4357039	56.3753533	65.4598725	58.1532971	54.5745961	55.6143468
RANK	2	7	4	1	3	6	5

## Raw data and preliminary analysis

ndB	1	2	3	4	5	6	7	8
	89.0308999	-13.869446	2.04119983	-11.055102	-11.9382	6.02059991	-11.760913	89.0308999

Samples Visible Without Night Vision Equipment

Signal to Noise Ratio for Each Level and Variable and the Quantitative Absolute Differences between Levels

EFFECTS	A	B	C	D	E	F	G
L1	-3.5811627	-8.9102278	-3.9746396	19.0308999	-4.3995383	-9.0704733	-4.0060614
L2	-4.3995383	0.92952675	-4.0060614	-27.011601	-3.5811627	1.08977224	-3.9746396
/L1-L2/	0.81837568	9.83975451	0.03142187	46.0425008	0.81837568	10.1602455	0.03142187
RANK	4	3	7	1	5	2	6

# Specification Defects as Reported by Observation Crew

Raw data and preliminary analysis

Number of Defects

Night 1

Night 1

(SMALLER THE BETTER)

L(8)	A	B	C	D	E	F	G	B1	B2	B3	B4	B1	B2	B3	B4	TOTAL	SUM Y^2	ndB
1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	0	1	1	9.0309
2	1	1	1	2	2	2	2	2	2	5	8	3	0	5	7	33	185	-13.641
3	1	2	2	1	1	2	2	2	1	3	3	1	2	4	1	15	41	-7.0969
4	1	2	2	2	2	1	1	1	1	2	5	1	0	8	1	21	105	-11.181
5	2	1	2	1	2	1	2	2	3	6	6	1	1	10	3	33	201	-14.001
6	2	1	2	2	1	2	1	1	0	1	0	0	0	1	2	4	6	1.24939
7	2	2	1	1	2	2	1	2	2	6	4	3	4	3	2	28	110	-11.383
8	2	2	1	2	1	1	2	0.0001	0	0	0	0	0	0	0	0.0001	1E-08	89.0309

1.125 3 3.25 1.125 0.875 3.875 2 1.625

ndB  
1 89.0308999  
2 -13.869446  
3 2.04119983  
4 -11.055102  
5 -11.9382  
6 6.02059991  
7 -11.760913  
8 89.0308999



Specification Defects as Reported by Observation Crew

Signal to Noise Ratios for Each Level and Variable and the Quantitative Absolute Differences between Levels

EFFECTS	A	B	C	D	E	F	G
L1	-5.7219623	-4.3403977	18.2594888	-5.8625316	23.0535621	18.2199365	-3.0709332
L2	16.2240499	14.8424853	-7.7574013	16.3646192	-12.551475	-7.7178489	13.5730208
/L1-L2/	21.9460122	19.182883	26.0168901	22.2271508	35.6050367	25.9377854	16.643954
RANK	5	6	2	4	1	3	7

# Samples Receiving an ARDEC Rating of 0 - "Totally Blind"

Raw data and preliminary analysis

Number of Defects

Night 1

Night 2

(SMALLER THE BETTER)

L(8)	Barrel #'s								Barrel #'s								TOTAL	SUM Y^2	ndB
	A	B	C	D	E	F	G	B1	B2	B3	B4	B1	B2	B3	B4				
1	1	1	1	1	1	1	1	0.0001				0	0	0	0	0	0.0001	1E-08	89.0309
2	1	1	1	2	2	2	2	3				7	0	4	8	2	33	195	-13.869
3	1	2	2	1	1	2	2	0				1	0	0	0	0	3	5	2.0412
4	1	2	2	2	2	1	1	2				4	0	8	1	0	20	102	-11.055
5	2	1	2	1	2	1	2	3				5	0	8	1	0	23	125	-11.938
6	2	1	2	2	1	2	1	0				0	0	1	0	0	2	2	6.0206
7	2	2	1	1	2	2	1	3				5	4	4	2	4	30	120	-11.761
8	2	2	1	2	1	1	2	0.0001				0	0	0	0	0	0.0001	1E-08	89.0309

ndB

1	89.0308999
2	-13.869446
3	2.04119983
4	-11.055102
5	-11.9382
6	6.02059991
7	-11.760913
8	89.0308999

Samples Receiving an ARDEC Rating of 0 - "Totally Blind"

Signal to Noise Ratios for Each Level and Variable and the Quantitative Absolute Differences between Levels

EFFECTS	A	B	C	D	E	F	G
L1	16.5368879	17.3109633	38.1078602	16.8432467	46.5308999	38.7671244	18.0588713
L2	17.8380967	17.0640213	-3.7328756	17.5317379	-12.155915	-4.3921398	16.3161133
/L1-L2/	1.30120883	0.24694201	41.8407358	0.68849121	58.6868151	43.1592642	1.74275804
RANK		5	6	2	4	1	3
							7

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